Fractal interfaces in dielectric waveguides

P. J. Roberts[1,2], F. Couny[1,2], H. Sabert[2], B. J. Mangan[2], D. P. Williams[2], L. Farr[2],
T. A. Birks[1], J. C. Knight[1] and P. St.J. Russell[1],
[1] Blaze Photonics and [2] Department of Physics, University of Bath, Claverton
Down, Bath BA2 7AY, United Kingdom.

Ultimately the loss of a waveguide is dictated by irregularity or roughness along the guiding direction, if the constituent materials show negligible intrinsic loss and tunnelling or leakage loss is absent. The nature of the roughness, which is determined by the underlying physical processes that create it, has profound implications for the magnitude of the loss and how it scales with wavelength λ. Typically the roughness contains significant spectral power at length scales comparable to and greater than λ, so that the familiar $1/\lambda^4$ dependence of Rayleigh scattering is not observed. Indeed, the roughness at the air / glass interfaces in Photonic Crystal Fibres has been found to be fractal over many decades of length scale that straddle λ, resulting in a qualitative change in the wavelength scaling from the Rayleigh form. If the dimensions of the structure are considered as scaling with λ, the fractal form implies a $1/\lambda^3$ dependence of the interface roughness loss, but at a fixed structure size the dependence is more complicated. The paper will explore the wavelength dependence of roughness scattering loss due to fractal interface roughness for a variety of waveguide forms. In particular, it will be shown that a weak wavelength dependence typically results for waveguides which guide by total internal reflection.